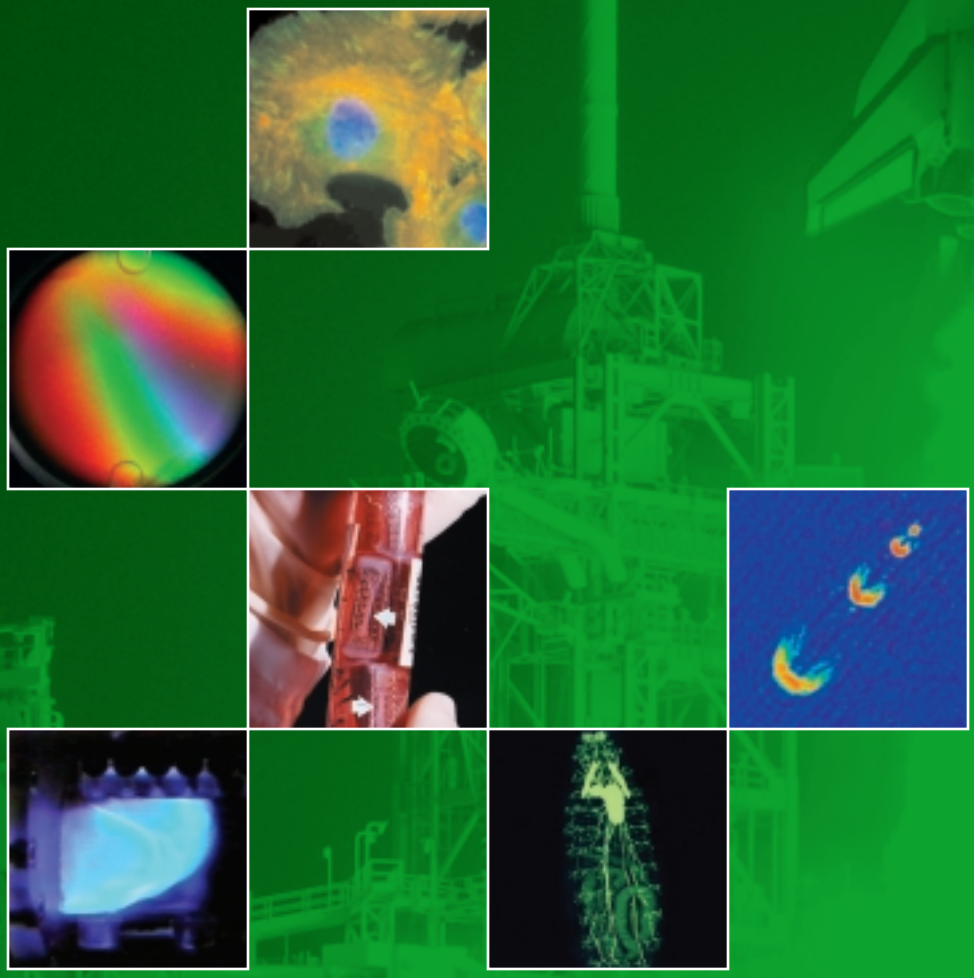
NASA's Biological and Physical Research

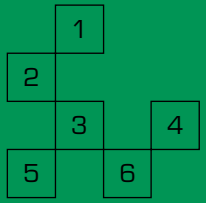
SPACE RESEARCH: TRANSFORMING TOMORROW TODAY



ABOUT THE FRONT COVER . . .

Background image: The Space Shuttle *Endeavour* rises into the twilight sky on mission STS-108. Liftoff occurred on December 5, 2001, at 5:19:28 p.m. EST. *Endeavour* docked with the International Space Station on December 7, 2001. STS-108 was the 107th Space Shuttle flight and the 12th flight to the International Space Station.

Tiled images: (see legend below for positions) 1) Fibroblast, the connective tissue of a cell, subjected to 50 times Earth's gravity; 2) high-quality, space-grown colloidal single crystals, uniformly dispersed and nearly the same size; 3) cultured muscles grown in the microgravity of space; 4) Wolfgang Ketterle's Nobel-Prize-winning first atom laser producing pulses of coherent matter; 5) water mist being developed as a replacement for bromine-based chemical fire suppression agents; 6) fluorescently stained developing nerve cells in a fruit fly.



National Aeronautics and Space Administration

Headquarters
Washington, DC

NASA'S Biological And Physical Research

SPACE RESEARCH: TRANSFORMING TOMORROW TODAY

Highlighting the Human Experience in Space: 2002

INTRODUCTION

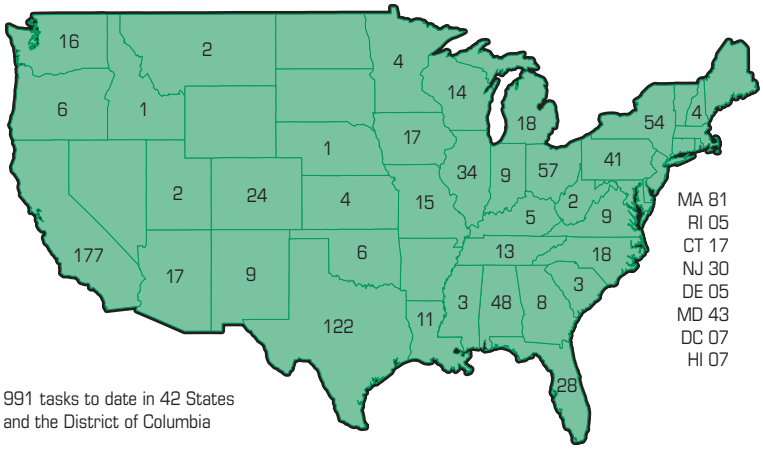
The Office of Biological and Physical Research (OBPR), established in 2000, affirms NASA's commitment to the essential role biology will play in the 21st century. OBPR will highlight its biological research on STS–107, a dedicated research mission scheduled to fly in the summer of 2002. Revolutionary solutions to science and technology problems are likely to emerge from scientists, clinicians, and engineers who are working at the frontiers of their respective disciplines and are also engaged in dynamic interdisciplinary interactions. OBPR will foster and enhance rigorous interdisciplinary research closely linking fundamental biological and physical sciences. OBPR is dedicated to using the unique characteristics of the space environment to understand biological, physical, and chemical processes; conduct science and technology research required to enable humans to safely and effectively live and work in space; transfer knowledge and technologies for Earth benefits; and support investment in space research by the private sector.

Advances in biology, medicine, physics, chemistry, associated analytical tools, and information systems have opened an era of unprecedented opportunities for bringing space-based knowledge to benefit human life on Earth. This increased understanding will transform the technological foundations, not only of the space program, but also of our society. NASA researchers stand on the brink of using this knowledge to develop "smart" materials and "intelligent" spacecraft systems that are programmed to sense changes and adapt to them, a capability that will enable widespread advances in Earth-based technology, engineering, biomedical, and commercial products through insights gained in space.

An exciting validation that science should drive missions is that the ISS Research Capability budget was transferred to this NASA Enterprise for FY 2002 and beyond. This means that OBPR will now manage both the equipment that will provide the capability to conduct research onorbit and the research itself. For FY 2002, the OBPR budget is approximately $850, 000,000, over twice the FY 2001 budget.

OBPR Increased Research Tasks for FY 2000

991Total Research Investigations by State



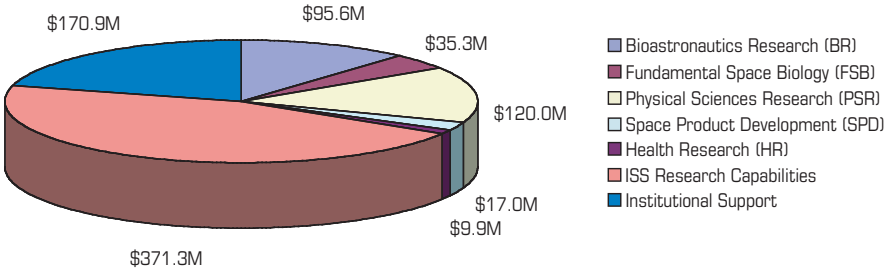
STS-107—OBPR RESEARCH MISSION

STS-107 is a dedicated research mission using the Double-Research Module provided by Spacehab, Inc. The research being conducted by OBPR on STS-107 is multidisciplinary, involving experiments in all of the OBPR scientific research areas. Fundamental biology experiments will investigate the effects of the space flight environment on various biological systems including plant growth, bacterial and fungal physiology and virulence, central nervous system functioning, and blood flow regulation. An integrated suite of biomedical experiments will examine sleep-wake cycles, the immune system, and protein and calcium metabolism in the crew during the mission. In addition, a potential countermeasure to lessen the risk of renal stone formation will be tested. Physical sciences experiments in combustion, material sciences, and biotechnology will be carried out, and commercial studies related to agriculture, cancer research, drug design, and materials for chemical processing will be conducted. The crew of seven, including the first Israeli astronaut, is scheduled to carry out this complex research agenda over a span of 16 days in July 2002.

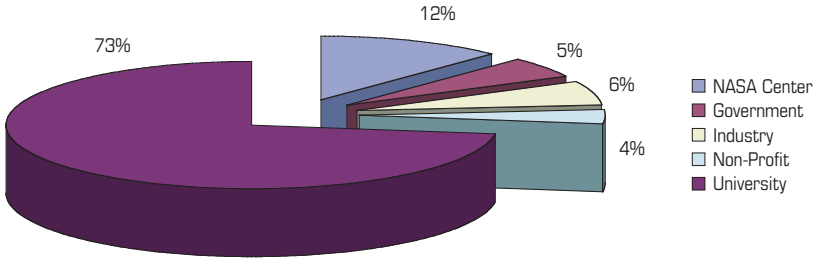
FY 2000 ACCOMPLISHMENTS

In FY 2000, OBPR funded over 800 Principal Investigators in 42 States working on peer-reviewed flight research and related ground-based projects that have been consistently making contributions to our understanding of biological, biomedical, and physical processes in space. In FY 2000, 1,635 scientific articles were published in peer-reviewed journals and 44 patent applications were submitted. These investigators and their students–1,809 high school, college, and doctoral students in FY 2000–represent significant segments of the national research communities in biological, biomedical, chemical, engineering, physics, and materials science. In FY 2000, over 140 industry affiliates participated in Commercial Space Center (CSC) research. In addition, there was also approximately $48M in non-NASA funds leveraged through the commercial research program.

FY 2002 OBPR Budget by Program
Total $820.0M



OBPR Principal Investigators' Institutions
FY 2000



PEER-REVIEWED RESEARCH

Overview: OBPR's programs of research and technology development rely upon broad participation by researchers from academia, Government agencies, and industry. All OBPR-supported science and technology research projects are peer-reviewed, and 95 percent of these projects are selected from open national competition.

In selecting investigations and projects to support—and ultimately for access to space—OBPR follows peer-review processes appropriately designed for scientific research, technology research and development, and commercial research. Our peer-review processes ensure the competitiveness and quality of OBPR research. There is also an established process and set of criteria governing the selection of commercial research payloads.

The variety of mechanisms used to select peer-reviewed projects include the following:

- investigator-initiated, peer-reviewed research through NASA Research Announcements;
- focused team research to produce countermeasures by National Space Biomedical Research Institute;
- countermeasure evaluation and validation;
- cooperative agreements and Memorandums of Understanding with other Federal agencies; and
- national specialized centers of research and technology.

OBPR implements its research programs through ground-based projects including the use of unique NASA facilities such as drop towers, centrifuges, and bed-rest facilities. The flight research programs use the full spectrum of platforms, from the KC-135 aircraft's short-duration parabolic trajectories to robotic free-flying spacecraft, the Space Shuttle, and now the ISS.

EDUCATIONAL OUTREACH AND PUBLIC OUTREACH

Overview: A citizenry well informed in mathematics, science, and engineering is critical to the United States' social and economic global leadership. Inspiring our youth toward careers in math, science, and technology is a high priority. The Office of Biological and Physical Research communicates the Enterprise's unique space research to inspire academic excellence; to explain how our research benefits life on Earth, as well as advances the capability of long-duration human exploration; and to increase the general scientific literacy of our Nation.

Educational Outreach and Public Outreach programs begin with grades K–12 and continue through lifelong learning opportunities. OBPR Educational Outreach activities include teacher, faculty, and student preparation and enhancement programs. Student programs allow students to have "real-time" experiences with science labs and procedures. Teacher workshops focus on activities that connect space research with national standards curricula. At the higher learning level, OBPR provides undergraduates with summer internships in research at one of the OBPR research Centers and invites applications from promising graduate students to participate in annual fellowship programs that support research in the biological and physical research disciplines. Doctoral scientists are provided with opportunities for research on problems, largely of their own choice, that are compatible with the research interests of OBPR.

OBPR Public Outreach activities inform the public about the Earth benefits derived from space research. Insights that generate knowledge about human biology and medical research, biotechnology, and fundamental physical science research may enhance the quality of life; commercial research that uses the unique microgravity environment as a laboratory leads to the development of improved products and processes.

FUNDAMENTAL SPACE BIOLOGY PROGRAM

Overview: Fundamental Space Biology uses the microgravity environment of space to enhance our understanding of fundamental biological processes by developing the foundation required to 1) enable a long-duration human presence in space and 2) support other biologically related NASA activities. The Division applies this knowledge and technology to improve our Nation's competitiveness, education, and quality of life on Earth.

The research elements of the Fundamental Biology Program provide a continuum of research that investigates the role of gravity and other space flight factors at all levels of biological processing. These include cellular and molecular biology, developmental biology, organismal and comparative biology, gravitational ecology, and evolutionary biology. These elements are focused on answering key scientific questions aimed at achieving the goals of the Program, including determining the role of gravity in how living organisms develop, understanding how biological systems sense and respond to gravity, and determining how gravity has shaped the evolution of life on Earth.

Additionally, Fundamental Space Biology supports crosscutting biological research thrusts. These efforts capitalize on previous research accomplishments and expand the program into key specialized topic areas such as space neurobiology, which builds on the results from the Neurolab mission; gravitational radiobiology, which studies the interaction of microgravity and space environment radiation; space genomics, which focuses on gene function and expression in the space environment; and mechanisms of aging in space, which expands the current developmental biology program element to include studies of the full lifespan and focuses on the role of gravity on fundamental aging mechanisms. These research thrusts take advantage of recent advances in fields such as neurobiology and molecular biology, and they represent new opportunities for leveraging of resources through cooperative activities with the National Institutes of Health and the National Science Foundation.

Arabidopsis flowering plants in the root tray retrieved from the STS-104 mission—the first plant life cycle experiment (grown seed-to-seed) onboard the ISS using the advanced astroculture plant growth unit. This unit supports plant research for a maximum of six months in reduced gravity.

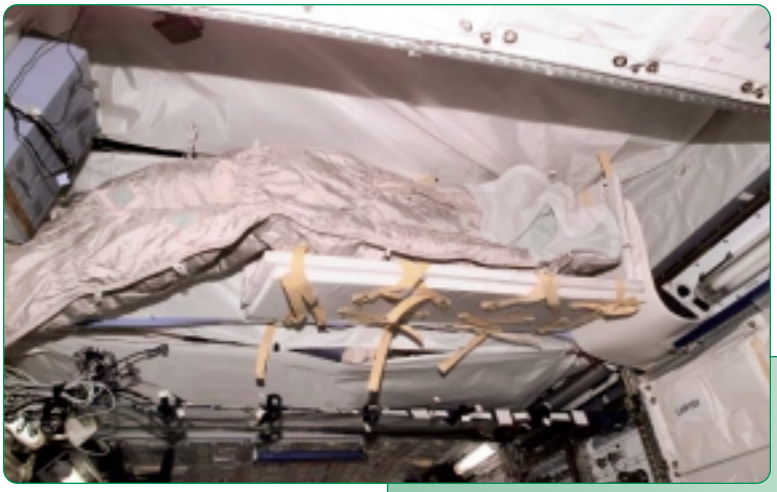
BIOASTRONAUTICS RESEARCH PROGRAM

Overview: Bioastronautics Research has two main objectives that support space flight crew health, safety, and performance. The first objective is to understand physiological and psychological adaptation to space flight in order to develop countermeasures and technologies that will mitigate risks to the crew. The second is to develop technologies that will augment spacecraft habitability, environmental controls, planetary habitability, and space systems.

The goals of the research in the Bioastronautics Research Program are to accomplish the following:

- understand the medical requirements for protecting human health and well-being during space flight,
- identify and characterize the medical risks of space flight for humans,
- determine the ways in which space flight changes how biomedical systems work,
- provide the scientific rationale and evidence that will lead to the development of preventive countermeasures for the negative effects of space flight,
- provide data and results that can be used by operational medicine to optimize crew health and performance, and
- develop advanced technologies to enable humans to live and work in space safely and effectively.

To achieve these goals, the Program sponsors research that provides answers to essential questions about space flight effects on human physiology, behavior/performance, radiation health, environmental health, and operational/clinical medicine. The research provides rational tests and evidence that enable the development and implementation of therapeutics, procedures, techniques, or equipment required to reduce flight medical, safety, and performance risks to acceptable levels. Technology development to augment spacecraft habitability, environmental controls, planetary habitability, and space systems technology is an essential element of work. The Program neither delivers medical care nor certifies crew health. It is responsible for integrating science and medical research to generate the knowledge required to enable flight crews to leave low-Earth orbit, perform their assigned tasks, and return to Earth with their health intact.

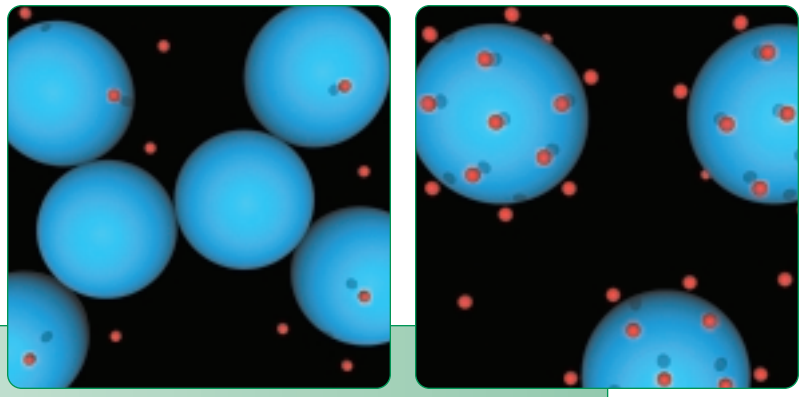


Polyethylene panels being installed to provide additional shielding from radiation in crew sleeping quarters of the ISS.

PHYSICAL SCIENCES PROGRAM

Overview: Physical Sciences research will utilize long-duration access to low-gravity conditions to overcome current barriers to scientific understanding, to resolve long-standing significant questions, and to open the door to new discoveries.

In an exciting collaborative effort with the Department of Energy Office of Science, Physical Sciences Research plans to fly the Alpha Magnetic Spectrometer (AMS), a three-year International Space Station experiment in fundamental physics to resolve the issue of the existence of antimatter, to probe for the presence of theoretically predicted dark matter, and to determine the composition of high-energy cosmic particles found in space. The results will significantly impact our ability to explain the details of the physics of the evolution of the universe after the initial formation. The microgravity environment will also enable some very precise experiments targeting the behavior of atoms, the building blocks of all matter. In particular, planned experiments on Bose-Einstein condensates, dubbed "The Coolest Gas in the Universe" by the December 2000 issue of *Scientific American* magazine, are predicted to yield technology that will allow a 100-fold improvement in the accuracy of atomic clocks, which will lead to ultra-precise space navigation and more definitive tests of Einstein's fundamental theory of gravitation. A more detailed understanding of atoms' behavior and the development of the ability to manipulate them will lead to unprecedented control over the design of new useful materials, as well as to new discoveries on how matter is assembled from its basic elements. Another example of cutting-edge research, only possible in microgravity, can be found in the field of combustion science, where accurate measurements can finally be carried out in the highest temperature region of flames. This capability will allow a better understanding of the important factors in the burning processes of fuels and in the formation of polluting by-products, which will significantly impact the energy production industry on Earth.



The pictures shown here reflect concentrations of colloidal particles (blue) and nanoparticles (red) contained in fluids. NASA-funded researchers at the University of Illinois discovered a new approach for suspending fine particles in fluids, called "nanoparticle haloing," which stabilizes particles in fluids to prevent them from otherwise organizing themselves or coagulating into a disordered gel-like structure. Through the use of nanoparticle haloing, the behavior and structure of materials in fluids (colloidal suspensions) can be controlled. Paint is an example of a fluid that contains suspended colloidal particles. If such particles become unstable, they clump together, causing the paint to thicken substantially, which limits the product's shelf life. By tailoring the interactions between particles, researchers were able to engineer the desired degree of colloidal stability into the mixture.

RESEARCH INTEGRATION PROGRAM

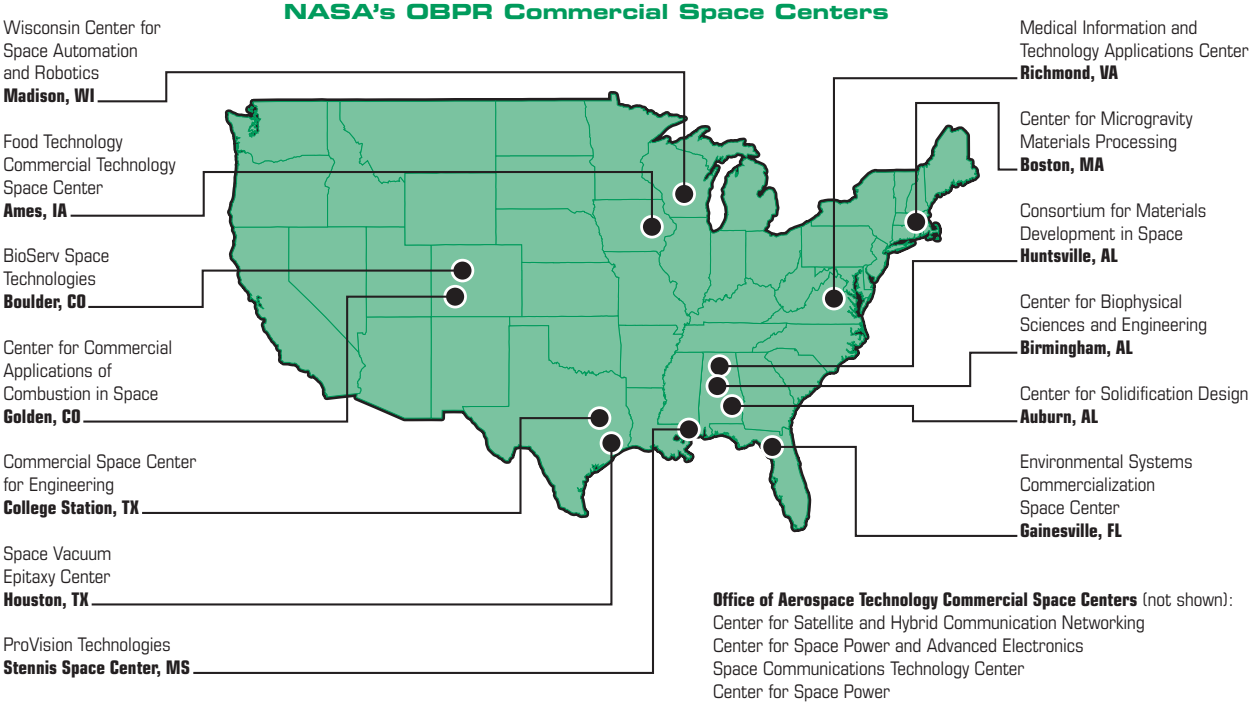
Overview: The Research Integration Program manages the payload manifest process for the Office of Biological and Physical Research. The Division also collaborates with the Office of Space Flight, Office of Earth Science, and Office of Space Science in exploration mission planning, ISS-based partnerships, and the potential non-Government organization (NGO) interface to the ISS. Included in their responsibilities are the planning of commercial activities, including the Commercial Space Centers; commercial outreach; and managing flight research payloads.

Through NASA-sponsored agreements and the CSCs, new or improved product research in fields as diverse as agriculture/plant growth, pharmaceutical products, new sensor technology, refining processes, combustion research for improved fuel efficiency, materials development, electronics, and other endeavors will be enhanced through insight gained by research conducted in the unique environment of space. Such efforts help fulfill NASA's mandate to support the commercial use of space. Several commercial research payloads in agriculture and biotechnology have flown on the ISS, with additional payloads being readied for flight during FY 2002.

NASA has noted a distinct advantage in placing commercially driven researchers in the same organization as those conducting basic science. While maintaining a distinct commercial focus, organizational location facilitates the use of basic research advances to support new product development. Commercial researchers help translate research results into possible applications. There is synergy and leverage through the use of hardware and joint experiment planning. In FY 2002, four CSCs previously managed by the Office of Aerospace Technology were transferred into OBPR. Now OBPR manages all CSCs. Moving these four CSCs into OBPR will renew focus on the commercial power and communications markets where further synergies and cost savings may be realized.

Commercial research in both the biological and physical sciences encourages industry to use insights gained in the environment of space to foster new or improved products and services on Earth through collaboration with the Commercial Space Centers and the entrepreneurial process.

NASA's OBPR Commercial Space Centers



Office of Aerospace Technology Commercial Space Centers (not shown):
Center for Satellite and Hybrid Communication Networking
Center for Space Power and Advanced Electronics
Space Communications Technology Center
Center for Space Power

LEFT: A student participates in science learning experience during education live broadcast during the Pan Pacific Basin Micro-G Conference, May 2001. **RIGHT:** A highlight of FY 2001 was the selection of an OBPR Principal Investigator's research to receive the Nobel prize for physics. Dr. Wolfgang Ketterle is the first person to produce pulses of coherent matter—the equivalent of a pulsed laser beam, but for matter. Dr. Wolfgang Ketterle, (center) 2001 Nobel Laureate in Physics, is congratulated by Dr. William Phillips, OBPR PI and 1997 Nobel Laureate in Physics, and Dr. Mark Lee, NASA Enterprise Scientist for the OBPR Fundamental Physics Program.

CURRENTLY PLANNED EVENTS

NASA is currently conducting research on the International Space Station. A dedicated Space Shuttle research mission, STS-107, is also scheduled for launch in the summer of 2002. In addition to a series of combustion experiments, research questions addressed in this mission focus on crew health and safety and ISS risk mitigation, along with several commercial research payloads in agriculture, materials development, and biotechnology. At the end of FY 2002, over 45 experiments will be flown or are currently onorbit on the ISS.

In addition, in FY 2002, OBPR is undertaking a significant activity to reprioritize ISS research activities post-FY 2004. Expert scientists, academia, and commercial researchers will be assisting in this effort through a series of plenary sessions. A final report to the NASA Administrator and NASA Advisory Committees in the late summer will result in a restructured program for FY 2004 and beyond.

OBPR is continuing to identify other research opportunities on Space Shuttle flights to the ISS, particularly for fundamental biology and ISS hardware and countermeasure development risk mitigation experiments during the period of ISS assembly.

Information concerning OBPR's FY 2001 accomplishments and experiments on upcoming research missions appear as Fact Sheets in the cover pockets of this publication. This information will help the reader become more familiar with the exciting advances in OBPR research.

To learn more about OBPR's "Biophysical" world, please visit *http://SpaceResearch.nasa.gov*

ABOUT THE BACK COVER . . .

Background image: As seen in a wide view from a digital still camera aimed through a window on *Endeavour*'s aft flight deck, the International Space Station (ISS), continuously staffed since 1999 with a three-person crew, is backdropped against dark space over Earth's horizon following the Space Shuttle's undocking on December 15, 2001.

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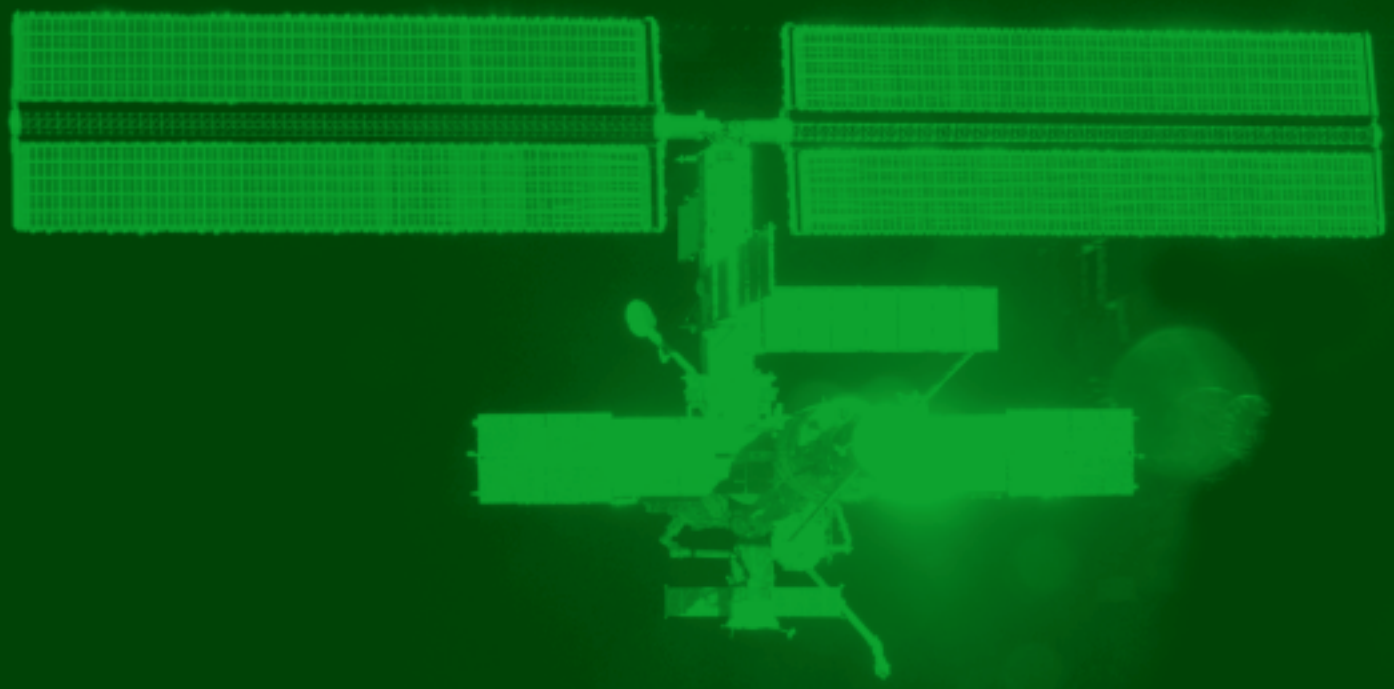

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